2001 Proceedings of the 23rd Annual EMBS International Conference, October 25-28, Istanbul, Turkey

MONOCHROME IMAGE REPRESENTATION AND SEGMENTATION BASED ON THE PSEUDO-COLOR AND PCT TRANSFORMATIONS

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Abstract-**Monochrome image representation and segmentation based on the pseudo-color transformation and principal components transform (PCT) are presented in this paper. The HLS family of color models is employed to map a monochrome image into a new multidimensional color space where image features are enhanced by color representation. An optimal decomposition is then applied using the PCT transformation of the color space, in which image features are better defined and the automatic image segmentation is easily performed using the PCT-guided median splitting. Attempts are also made to compare the proposed segmentation with the fuzzy c-means (FCM) clustering in terms of the quality and computational complexity involved in segmentation. Results from mammograph and MRI image representation and segmentation are presented.**
Keywords - **Color model, pseudo-color transformation, PCT, segmentation, fuzzy c-means**

I. INTRODUCTION

A color model is a 3D coordinate system used to represent a particular color organization [1]. Various application-oriented color models, such as the CMY, YIQ, LHS and HSV models for color image manipulation can be derived from the RGB model by linear/nonlinear transformations. How to use color models in image processing is still a challenging task. A color image can be represented the way humans perceive colors using the HLS family of models (HLS, HSV, GLHS [2]), in which not only intensity, but also hue and saturation are provided for more accurate image processing and analysis. For monochrome images of low quality, pseudo-color processing has been employed where traditional image enhancement was unable to improve image contrast and clarity [1]. Algorithms on color image segmentation have been suggested [3-5]. A pseudo-color transformation using the HLS family of models is presented in this paper as a way to map the monochrome image into a three dimensional RGB color space, in which segmentation is implemented.

Applications in medical image contrast enhancement and segmentation are introduced. Pseudo-color transformation is used in the representation of mammographic images. With PCT, stronger color image representations with the corresponding three RGB components are displayed, which provide radiologists with additional information for analysis. Based on the pseudo-color and PCT transformations, an automatic image segmentation is implemented where PCT is applied to 3D color space, resulting in uncorrelated new components, which makes automatic classification and segmentation possible by simply median splitting the histogram of each component. Results from mammograph and MRI images were selected, which are also compared to that using the fuzzy c-means (FCM) algorithm [6] and the traditional edge filtering method [7], showing good performance of the proposed segmentation method.

II. METHODOLOGY

Linear or non-linear image intensity transformation is the traditional method used to change the image contrast. Here, a novel transformation of mapping the image intensity to the multidimensional color space is introduced.

1) *Pseudo color transformation using the HLS family of models*: The purpose of pseudo-color transformation is to transform gray level differences to color differences by assigning the gray image to hue (H). The light/value (L/V) and saturation (S) components are original or scaled values of the image intensities. The transformation result is then represented in terms of a RGB color image, in which small difference between two gray levels can be differentiated by the distance between the [r g b] vectors of two points in the color space. The proposed color transformation is similar to a weighted classification, in which the weights are proportional to the gray level. Fig. 1 shows the diagrams of the gray level (0~255) to RGB color space transformation using the HSV color model. Multi-channel images can also be inputted into a color model to fuse information in color space.

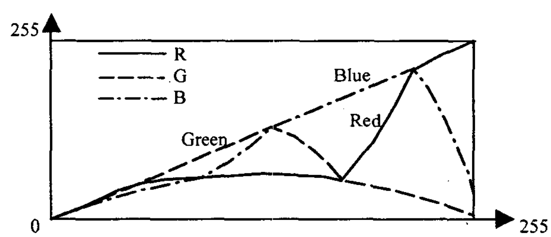


Fig. 1. Pseudo-color transformation using HSV color model

2) *Principal component transformation in color space:* PCT transform (Karhunen-Loève transform) has been used in color image processing [4-5] as a means to project the RGB components on the eigenvectors of the covariance matrix (principal components). The transformed image includes one color plane with the maximum variance. Given pixel's RGB vector: x=[r g b], the 3D covariance matrix is computed using the following equations:

$$m_x = \frac{1}{N}\sum_{n=1}^{N} x_n \,, \qquad (1)$$

$$C_x = \frac{1}{N}\sum_{n=1}^{N} x_n \cdot x_n^T - m_x \cdot m_x^T , \quad (2)$$

where N is the number of pixels, m_x is the mean vector, and C_x is the covariance matrix. The eigenvector matrix A is used to project the data set in color space onto the principal components. By scaling the resulting component vector $X = A \cdot x$ to the range of 0~255, a new color image is generated, in which the components are uncorrelated and the variance between components is maximal. The component corresponding to the largest eigenvalue contains the largest variance. The second component is orthogonal. Although smaller variance is contained in the third component, smaller changes such as noise and fine details emerge. There is also larger discriminate power in features in the new color image. Therefore, a PCT transformed image shows better feature contrast in both color representation and separate component.

3) *PCT-Guided automatic segmentation*: Thresholding method is a popular approach for image segmentation [1]. Many methods are proposed to find the optimal single or multiple thresholds based on the intensity histogram of the image [8]. If an image is complicated and noisy, it is difficult to find a proper threshold automatically. Additionally, the region of interest in image such as X-ray or MRI contains mostly smooth boundaries, thus the traditional edge detection filters cannot locate the boundaries accurately. Based on the color image segmentation using PCT and the median split introduced in [4], an automatic monochrome image segmentation using pseudo-color and PCT transformations is presented. With PCT, image features with different discriminate powers are derived, median split is then performed to automatically split the color space, and each pixel is mapped into the closest color region. The segmentation procedure is as follows:

1. Compute the histograms from the PCT transformed three component images [X_1 X_2 X_3];
2. Find the threshold vector [t_1 t_2 t_3] that divides each component into two groups, each having an equal number of points;
3. Divide the RGB color space into 8 regions using the thresholds, each region is then assigned a certain color;
4. A region that contains a small number of pixels is merged into a nearby larger region, resulting in final segmentation.

Compared to the automatic thresholding method in [8], the PCT-guided segmentation is also based on the statistical properties of the image. However, the PCT components already contain the optimal thresholds for segmentation using median split. Therefore, the computational complexity is reduced and less time will be spent in the threshold finding procedure. Here, we employed the FCM clustering method to evaluate the performance of PCT-guided segmentation.

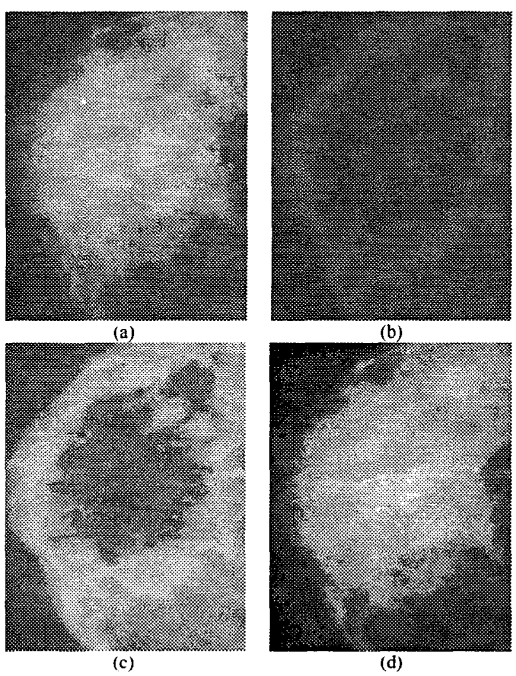
4) *FCM-based segmentation:* Fuzzy c-means (FCM) has been used as a clustering technique in image classification and pattern recognition, and has received extensive attention in medical image such as MRI brain image segmentation [6]. FCM is an iterative clustering approach. It partitions the data set $D=\{d_1, d_2, \ldots, d_N\}$ into NK fuzzy subsets. Given an image having N pixels, with NK classes, each pixel represented by NC channels, the data set D is an NC-dimensional vector. When FCM is used to segment the PCT transformed data set, NC=3. FCM clusters the data set by minimizing the sum of a squared error of the objective function [6], the calculation contains many iteration steps. In the examples presented in this paper, approximately 10 to 20 iterations were required for the minimization process.

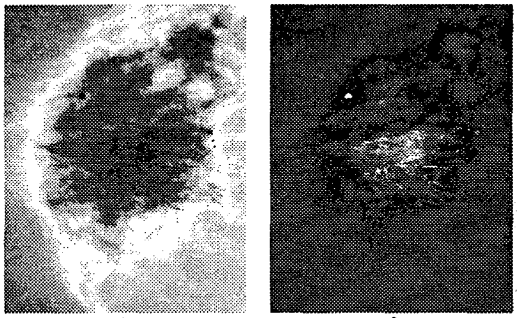
III. RESULTS

Pseudo color image representations based on color model and PCT transformations were applied to medical images. PCT-guided method and FCM clustering were used in pseudo color image segmentation, and comparisons were made using mammograph and MRI brain images. Finally, an image edge detection has also been derived using the proposed method.

A. Mammograph image transformations

Pseudo-color transformation is suitable for X-ray image enhancement due to the smooth and low contrast nature of the image. Fig. 2 shows the color image representation of a right cranial-caudal mammograph using HSV and PCT transformations. There is an abnormal region in the center, with a lesion-type calcification and fine-linear-branching distribution. Color transformation enhances the contrast of the image, and makes the features easily visible in both the color transformed and component images.



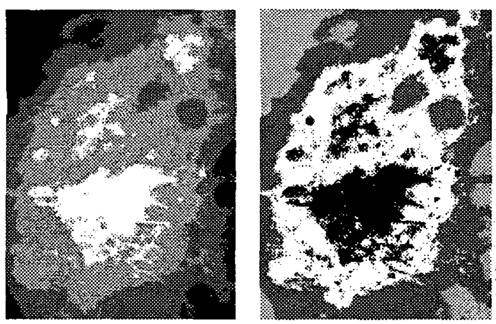


(e) (f)

Fig. 2. Pseudo-color image representation based on HSV and PCT transformations. (a) Mammograph from the Digital Database for Screening Mammography of the University of South Florida: C_0341_1.RIGHT_CC; (b) Pseudo-color transformation using HSV color model; (c) PCT transformation of (b); (d-f) RGB components of (c).

B. Mammograph image segmentation

Like other X-ray images, mammograph is too smooth to visually locate accurate region boundaries. The pseudo-color transformation and PCT-guided segmentation approaches demonstrate their utility to enhance and segment the internal features and regions. Fig. 3 shows the PCT-guided image segmentation and FCM-based segmentation results based on the color space transformation shown in Fig. 2. The input data set of FCM is from the PCT transformed image X, therefore, the FCM data set is $D=X$ with NC=3. The class number is set to NK=4. The two methods have similar results in segmenting the main regions and features in mammograph.



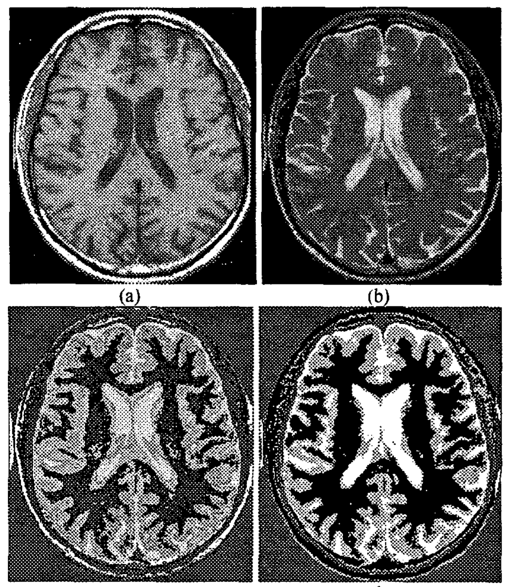
(a) (b)

Fig. 3. Mammograph image segmentation using the proposed and FCM-based segmentation methods. (a) Pseudo-color transformation and PCT-guided segmentation; (b) FCM-based segmentation (NK=4, NC=3).

C. MRI brain image segmentation

In MRI brain image segmentation, images from different acquisition methods are used to fuse the available useful feature information and compensate for the inhomogeneity in each image. Here, MRI T1 and T2 images are used in the PCT-guided and FCM clustering segmentation. It is supposed that there are four classes contained in a brain image: gray matter, white matter, CSF, and background. Fig. 4 shows segmentation of MRI brain images. In color transformation using the HSV color model, a T1 image was input to H and S, and a T2 image was input to V component. The data set used in FCM segmentation is T1 and T2 images, therefore, NC=2.

The similar segmentation results mean that the PCT-guided method is close to the optimal criteria that FCM used for classification. However, different computational complexities are contained in the two methods. The PCT-guided segmentation requires simply a pseudo-color transformation, PCT, and median splitting of each color component. The FCM-based segmentation includes iterative calculations of the memberships of different classes related to each sample and the cluster center of each class in the multi-channel data set [6]. The computational complexity depends not only on the image size, but also on the number of iterations and clusters. Therefore, the PCT-guided method is more computationally efficient than the FCM-based segmentation.



(c) (d)

Fig. 4. MRI image segmentation using the proposed and FCM-based segmentation methods. (a) MRI T1 image; (b) MRI T2 image; (c) PCT-guided segmentation; (d) FCM-based segmentation (NK=4, NC=2).

D. Edge detection in MRI image

It is difficult to locate edges in medical images because the boundaries are either blurred or distorted by noise due to the nature of the acquisition equipment and/or the tissue features. Here, the edge detection based on the proposed PCT-guided image segmentation was experimented on MRI human body images. Because the second and third components of PCT transformed image contain more fine details and noise, smoothing is needed before median splitting. Fig. 5a is an MRI image from the Visible Human. Fig. 5b is the color representation after pseudo-color and PCT transformations. Fig. 5c shows the edges detected in the first and second PCT

components, and Fig. 5d is the edge detection using the Canny edge detector [7]. It is found that the boundaries of the smooth regions and small organs that cannot be detected by the edge filtering are clearly delineated using the proposed segmentation method. The proposed edge detection can be used for any other kind of monochrome images.

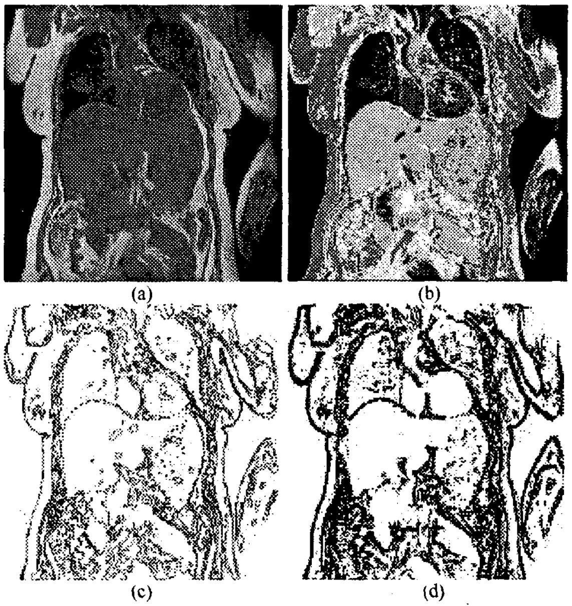


Fig. 5. MRI image edge detection using the PCT-guided segmentation method and edge filtering method. (a) Original MRI image from the Visible Human; (b) Color image representation using HLS-based pseudo-color and PCT transformations; (c) Edge detection based on PCT-guided segmentation; (c) Edge detection using the Canny operator.

IV. Discussion

The proposed pseudo-color and PCT transformations can be used in a wide range of image applications, such as monochrome image pseudo-color representation, image enhancement, region segmentation, and edge detection, especially when traditional methods are not applicable. The PCT-guided color space segmentation is close to the optimal criteria that FCM used in clustering different classes of a data set. Therefore, the PCT-guided segmentation can substitute for the FCM-based segmentation when computational efficiency is required. The pseudo-color transformation is a form of 3-dimmensional mapping. Instead of applying the proposed method to single monochrome images, multi-channel images can also be processed. Although other linear or non-linear transformations may exist, the proposed image transformation can be visualized in terms of color image representation, and the advantage is that the information in the original image can be totally preserved. Finally, the proposed transformation and segmentation approaches are simple and fast, which can be implemented in real-time.

V. Conclusion

In this paper, an efficient pseudo-color transformation and segmentation method based on the HLS family of color models and the PCT is presented. Compared to other automatic segmentation methods such as Fuzzy c-means clustering and image edge filtering, the proposed segmentation method is simple, flexible, robust, and computationally efficient.

Acknowledgment

This Work is in part support by NIH CA85594 (EXW) and NIH R29 14715 (DG).

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